Abstract: What do data science and the foundations of quantum theory have to do with one another?

A great deal, it turns out. The particular branch of data science known as causal inference focuses on a problem which is central to disciplines ranging from epidemiology to economics: that of disentangling correlation and causation in statistical data.

Meanwhile, in a slightly different guise, this same problem has been pondered by quantum physicists as part of a continuing effort to make sense of various puzzling quantum phenomena. On top of that, the most celebrated result concerning quantum theory’s meaning for the nature of reality – Bell’s theorem – can be seen in retrospect to be built on the solution to a particularly challenging problem in causal inference.

Recent efforts to elaborate upon these connections have led to an exciting flow of techniques and insights across the disciplinary divide.

Perimeter researchers Robert Spekkens and Elie Wolfe have done pioneering work studying relations of cause and effect through a quantum foundational lens, and can be counted among a small number of physicists worldwide with expertise in this field.

In their joint webcast from Perimeter on October 7, Spekkens and Wolfe will explore what is happening at the intersection of these two fields and how thinking like a quantum physicist leads to new ways of sussing out cause and effect from correlation patterns in statistical data.

Watch live online at insidetheperimeter.ca.
THE QUANTUM PHYSICIST
as Causal Detective

Robert Spekkens and Elie Wolfe
Perimeter Institute
Oct. 7, 2020
Amount of damage done by fire

Number of firefighters on scene
Number of firefighters on scene

Amount of damage done by fire
Number of firefighters on scene

Amount of damage done by fire

Size of fire
Amount of damage done by fire

Number of firefighters on scene
Amount of damage done by fire

Number of firefighters on scene
Taking the medication

Hidden factors such as being health-conscious

Recovering
Coin Flip → Taking the medication → Recovering

Hidden factors such as being health-conscious
Public Health Recommends the Treatment

Taking the medication

Hidden factors such as being health-conscious

Recovering
Degree from educational institution

Maximum Wages in Future Career

Hidden factors such as aptitude
Maximum Wages in Future Career

Degree from educational institution

Admission factors unrelated to aptitude

Hidden factors such as aptitude
### The evidence

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### The suspects

![Diagram showing the relationship between variables X and Y]
John Stuart Bell
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The 1st suspect

- Left outcome
- Right outcome
- Left setting
- Right setting
- Common Cause
The evidence

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The 2nd suspect

Compatible
The evidence

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The 3rd suspect

Left outcome

Right outcome

Left setting

Quantum common cause

Right setting
Violation of Bell inequalities

Witnessing quantumness

NOT THIS
“Eliminate the Impossible”

Causa 1964!
Causal Structures come in Great Variety
Abiotic Stress

Disturbance

Community Biomass

Plant Diversity

species count

DOI:10.1890/09-0464.1
50 years of experience
“The Inflation Technique for Causal Inference”
Classical vs. Classical

Classical vs. Quantum

Quantum vs. Quantum
Quantum Cryptography
Quantum Internet
Quantum vs. Quantum

Causal inference in the presence of quantum common causes
Hardware Diagnostics

[Diagram]

ai.googleblog.com/2018/05/the-question-of-quantum-supremacy.html
**Classical vs. Classical**

Physicists have experience

**Classical vs. Quantum**

Recognizing quantum advantages

**Quantum vs. Quantum**

Diagnosing quantum processes
THE CLUE in the Medicine Jar
Symptom: **Angina (chest pain)**

- Diabetes
- Rare conditions (<5% each)
- Pneumothorax (collapsed lung)
- Myocardial infarction (heart attack)
- Endocarditis (heart infection)
“Draw your assumptions before your conclusions.”

--- Miguel Hernán
Professor of Biostatistics and Epidemiology
Harvard University